Senior Thesis

An Examination of Potassium Alkali Feldspar Megacrysts From Castle Crags

by

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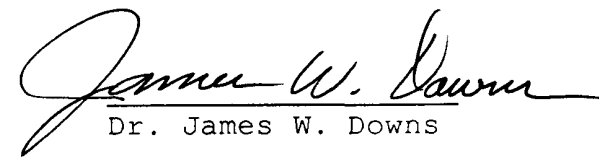

Dr. James W. Downs

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INTRODUCTION

The Al/Si distribution in potassium feldspar megacrysts collected from Castle Crags, California, is the subject of this paper.

Castle Crags is located approximately 80 km north of Redding, California, adjacent to Intersate Highway 5 in Shasta County. The pluton is situated within the Klamath Mountains and is one of ten bodies which intrude the Trinity Ophiolite. It is a slightly elliptical-shaped 30 km^2 epizonal stock which has been dated using K-Ar ages of hornblende and biotite that range from 224 to 133 m.y. (Lanphere and others, 1968). This intrusive body is concentrically zoned and is thought to have a complex history of fractional crystallization, second boiling, alkali transfer, and pressure quenching (Vennum, 1980).

There are three concentrically-arranged rock types which make up the majority of the pluton. The outermost zone is a fine-grained (1 mm) granodiorite, which represents a chilled border. The middle zone comprises the bulk of the pluton and is made up of a medium-grained (1-5 mm) porphyritic sodic

granodiorite that is characterized by the euhedral potassium feldspar megacrysts that are examined in this paper. The core is a fine-grained alkalic trondhjemite (Vennum, 1980).

Vennum (1980), who has done the most comprehensive study of the Castle Crags pluton, found that the contacts were gradational and he mapped these on the basis of textural features. The contact between the outer chilled granodiorite and the groundmass of the outer part of the porphyritic sodic granodiorite is placed at the first appearance of small potassium feldspar megacrysts (2 mm x 4 mm). The size of the megacrysts increases rapidly inward until maximum development (25 mm x 35 mm x 45 mm) is attained 200-300 m from the outer contact. Distribution of megacrysts is remarkably uniform throughout this facies. About 1200 m into the pluton from the outer contact of the porphyritic granodiorite, the size of the megacrysts begins to diminish and the crystals become less euhedral; about 2.5 m they are slightly larger than the groundmass.

A general outline of the composition of the pluton shows that modal potassium feldspar increases from a low of 10% to 12% in the outermost granodiorite to a high of 22% in the porphyritic granodiorite, and then decreases to 16-18% in the core; plagioclase remains fairly constant 60-65%. The overall felsic nature of the pluton is emphasized by the color index (i.e., the sum of the dark or colored minerals in

a rock expressed in percentages, 0-30 leucocratic), which drops from 10 to 12 in the outer granodiorite to values less than 1 in the trondhjemite (Vennum, 1980).

Moving from the geologic setting of Castle Crags, we shall now examine how the unit cell parameters of an alkali feldspar reflect its composition and its Al/Si distribution.

The average Al content of a tetrahedron is also called its Al site occupancy and will be denoted by $t_1$0, t_1m, $t_2$0 and t_2m for triclinic feldspars with $T_1$0, T_1m, $T_2$0, and T_2m tetrahedral sites. There are 16 tetrahedra in one unit cell with four of each type ($T_1$0, T_1m, $T_2$0, and T_2m) in triclinic feldspars. The refinement of a feldspar structure can allow one to find the Al content indirectly from mean T-O bond lengths <T-O> because Al-O bonds are substantially longer than Si-O bonds. The distribution of Al and Si markedly affects the b and c unit cell parameters. For example, in Figure 1, there are six sub-parallel paths along c in which we can follow ...T-O-T-O... paths through the feldspar structure; two of these are (starting near the origin) O_A1-$T_1$0-O_D0-T_2m-O_Bm-T_1m-O_A1 and, next to it, O_Bm-T_2m-O_D0-$T_1$0-O_A1-T_1m-O_Bm. All paths along c contain one $T_1$0 site, one T_1m site, and either one $T_2$0 or one T_2m site. Wright and Stewart (1968) found that to plot the b and c cell edges against each other produced more or less linear arrays for alkali feldspars of different composition but equivalent Al,Si order, regardless

of the symmetry of the specimen. Stewart and Ribbe (1969) assumed that the Low Albite-Low Microcline series was fully ordered, $(t_1O + t_1m) = 1.00$, and the Analbite-High Sanidine series fully disordered, $(t_1O + t_1m) = 0.5$, and contoured the b-c plot proportionally. This plot has been used in its updated form for this paper. MacKenzie and Smith (1955) used plots of the angles α^* versus γ^* as frames of reference to compare and interpret alkali feldspars from a variety of geologic terrains. The α^*-γ^* plot is bounded on one side by the Low Albite-Low Microcline exchange series, which is not strictly a straight line, as was the case in the b-c plot. Stewart and Ribbe (1969) showed that the α^*-γ^* plot could be used as quantitative measure of the difference in Al contents of T_1O and T_1m sites -- symbolically (t_1O-t_1m). In the ordered LA-LM series, $t_1O = 1.0$, $t_1m = 0$ and $(t_1O - t_1m) = 1.0$ (Kroll and Ribbe, 1983).

The purpose of this paper is to determine the Al/Si order-disorder, the range of order, and any relationship between phenocryst size and Al/Si order-disorder in the potassium feldspar megacrysts from Castle Crags, California.

METHOD

Feldspar megacrysts were chosen that showed no visible zoning, had no quartz inclusions, and were not highly weathered. The crystals were measured and two to three

specimens of the same size were selected. These were first crushed using a metal mortar and pestle, then further ground using a ceramic mortar and pestle. The samples were run through a 74-micron sieve.

Powder diffraction profiles were obtained using a Philips powder diffractometer with Ni-filtered CuKα radiation. They were scanned in one direction at 1/2 a degree 2θ per minute at 35Kv 15 ma. The samples were scanned from 12 degrees to 60 degrees at a chart speed of 30 in. per hour and a range of 500 and from 26 degrees to 29 degrees at a range of 1000. The samples were not run with an internal standard; however, a regression equation based on a silicon standard was used to correct the data (C. Corbató, private communication). In a trial run, the equation was not used and the subsequent results were grossly in error.

The patterns were then indexed under the assumption of being triclinic using a chart prepared by Bambauer and Bernotat (Ribbe, 1983). Two-theta values were obtained by measuring the peaks at 2/3 maximum height and then obtaining the d-spacings.

A least-squares refinement of the unit cell parameters was performed using the observed d-spacings. CC-1 was refined using the direct cell dimensions of intermediate microcline from Borg and Smith (1969). The refined cell

parameters of CC-1 were then used as starting parameters to refine CC-2 through CC-6. CELRF was the least-squares program that was used and it was written by C.T. Prewitt, who used C.W. Burnham's 1962 Lattice Constant Refinement program as a basis for his program. The refinement was done on $Q = 1/d^2$ assuming triclinic symmetry with no other contraints.

A b-c plot developed by Wright and Stewart (1968) was used to plot the observed data as well as a α^*-γ^* plot by MacKenzie and Smith (1955). Kroll and Ribbe (1983) derived the following equations for $(t_10 + t_1m)$ and $(t_10 - t_1m)$, which are respectively:

$$(t_10 + t_1m) = \frac{b - 0.7138 - 1.7505 \cdot c}{-7.7245 + 1.0150 \cdot c}$$

and

$$(t_10 - t_1m) = \frac{\alpha^* + 89.118 - 1.9902 \cdot \gamma^*}{-24.691 + 0.2229 \cdot \gamma^*}$$

RESULTS

TABLE 1: Observed d-spacings

hkl	d(Å) CC-1 (5 mm)	CC-2 (6 mm)	CC-3 (8 mm)	CC-4 (10 mm)	CC-5 (12 mm)	CC-6 (15 mm)
0 2 0	6.4449	6.4402	6.4356	6.4402	6.4589	6.4543
0 0 1	6.3529	6.3484	6.3529	6.3348	6.3665	6.3574
-1 1 1				5.8519	5.8558	5.8635
-2 0 1	4.2184	4.2066	4.2105	4.2204	4.2145	4.2224
1 1 1	4.0222	4.0133	4.0168	4.0240	4.0168	4.0258
1 -1 1	3.9395	3.9292	3.9499	3.9378	3.9447	3.9464
1 3 0	3.8437	3.8372	3.7888	3.8470	3.8454	3.8487
-1 3 0	3.7714	3.7604	3.7355	3.7667	3.7667	3.7730
1 3 -1	3.6732	3.6539	3.6554	3.6658	3.6613	3.6643
-1 3 1	3.6599	3.6015	3.5731	3.6058	3.6044	3.6073
2 2 1				3.5340		
2 2 -1		3.5271			3.5340	
1 1 -2	3.4650	3.4558	3.4637	3.4624	3.4624	3.4637

TABLE 1: Observed d-spacings (Continued)

hkl	d(Å) CC-1 (5 mm)	CC-2 (6 mm)	CC-3 (8 mm)	CC-4 (10 mm)	CC-5 (12 mm)	CC-6 (15 mm)
2 2 0		3.3302	3.3327	3.3096	3.3108	3.3144
-2 2 0		3.3036				
-2 0 2	3.2868	3.2785	3.2833	3.2809	3.2833	3.2845
0 4 0	3.2331	3.2296	3.2308	3.2262	3.2308	3.2308
0 0 2	3.2001	3.1855	3.1866	3.1855	3.1889	3.1900
1 3 1	2.9844	2.9844	3.0001	2.9864	2.9883	2.9962
2 2 -2	2.9253	2.9216	2.9632	2.9234	2.9272	2.9422
-2 2 2			2.9234			2.9290
0 4 1	2.8957	2.8920	2.8920	2.8939	2.8957	2.8939
1 3 -2	2.7632	2.7608	2.7699	2.7641	2.7649	2.7649
-1 3 2			2.7591			
3 1 -2		2.5990	2.5931	2.6019	2.6034	2.6004
2 4 -1		2.5665		2.5715	2.5715	2.5765

TABLE 1: Observed d-spacings (Continued)

hkl	d(Å) CC-1 (5 mm)	CC-2 (6 mm)	CC-3 (8 mm)	CC-4 (10 mm)	CC-5 (12 mm)	CC-6 (15 mm)
3 1 0	2.5503	2.5482	2.5517	2.5489	2.5510	2.5545
-3 1 0		2.5164	2.5475	2.5205	2.5178	2.5178
1 5 -1				2.4139	2.4114	2.4132
3 3 -1				2.3824	2.3800	
1 1 -3	2.3244	2.3221	2.3250	2.3250	2.3238	2.3244
-1 1 3					2.3198	
0 6 0	2.1630	2.1610	2.1595	2.1615	2.1615	2.1645
-4 0 2	2.1114	2.1218		2.1213	2.1242	2.1228
2 0 2	2.0696	2.0687	2.0691	2.0678	2.0678	2.0696
0 6 1				2.0495	2.0500	2.0513
4 2 -2		2.0111		2.0082	2.0077	
-4 2 2					2.0048	
2 2 2	1.9750	1.9734		1.9726	1.9718	1.9686

TABLE 1: Observed d-spacings (Continued)

hkl	d(Å) CC-1 (5 mm)	CC-2 (6 mm)	CC-3 (8 mm)	CC-4 (10 mm)	CC-5 (12 mm)	CC-6 (15 mm)
2 -2 2		1.9690				
4 0 0	1.9264	1.9245	1.9268	1.9252	1.9260	1.9268
-4 0 3		1.9202	1.9119	1.9130		1.9138
1 1 3	1.8516	1.8537	1.8548	1.8548	1.8558	1.8555
1 -1 3	1.8505				1.8512	1.8498
-2 0 4	1.7993	1.7966	1.7996	1.7986	1.7999	1.7999
0 2 4	1.5704	1.5682	1.5707	1.5702	1.5702	1.5702

TABLE 2: Unit cell parameters

	CC-1	CC-2	CC-3	CC-4	CC-5	CC-6
a	8.57(2)*	8.560(9)	8.57(1)	8.57(1)	8.567(7)	8.578(9)
b	12.96(2)	12.94(1)	12.93(2)	12.95(1)	12.956(8)	12.96(1)
c	7.187(8)	7.182(7)	7.196(9)	7.192(8)	7.194(5)	7.195(7)
α	90.0(2)	89.9(1)	90.2(1)	90.0(1)	89.96(8)	90.0(1)
β	116.0(1)	115.91(8)	116.00(8)	116.02(7)	116.01(5)	116.09(6)
γ	90.1(3)	89.8(1)	89.1(2)	89.9(1)	89.92(8)	89.89(1)
VOL.	717.(2)	715.(2)	717.(2)	717.(2)	717.(1)	718.(1)

* Values in parentheses are estimated standard deviations in the last decimal place.

TABLE 3: A1 site occupancies

	$(t_1O + t_1m)$	$(t_1O - t_1m)$	t_1O	t_1m	t_2O	t_2m
CC-1	.78	-.04	.37	.41	-.02	-.02
CC-2	.80	.05	.425	.375	.025	.025
CC-3	.88	.35	.615	.265	.175	.175
CC-4	.82	.02	.42	.40	.02	.02
CC-5	.83	.03	.43	.40	.015	.015
CC-6	.80	.06	.43	.37	.03	.03

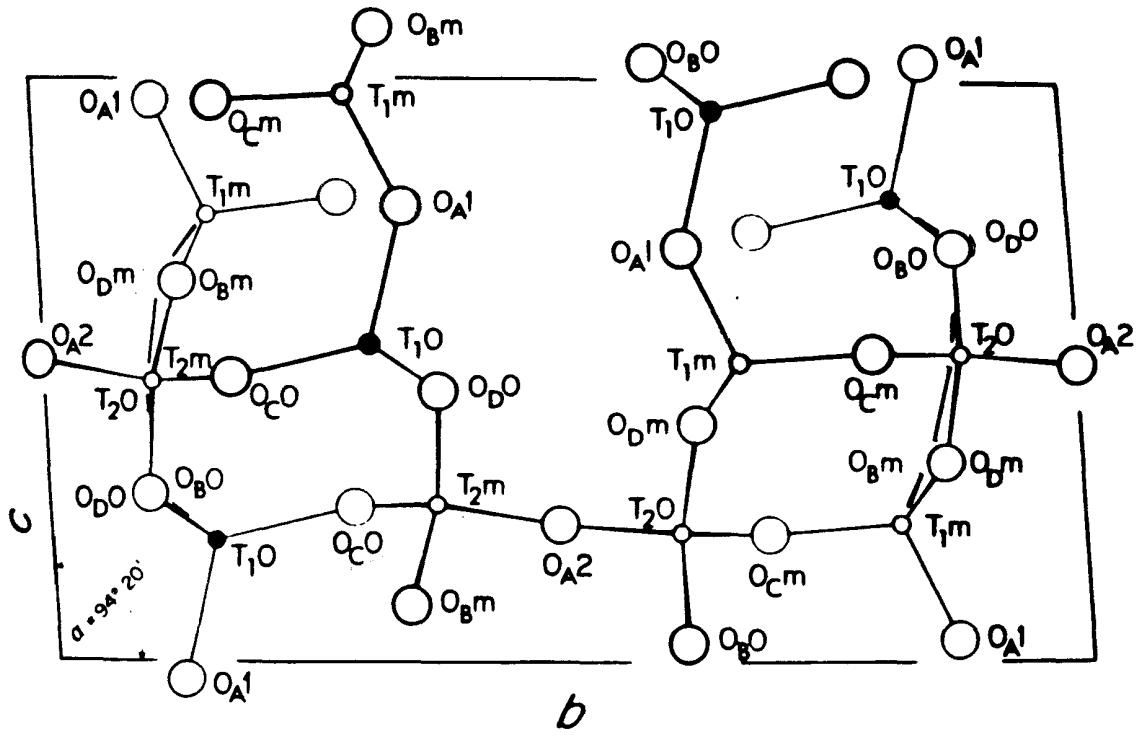

Figure 1. A projection onto (100) of part of the low albite structure. The T sites are the labelled small circles: T_1O contains Al (black dots); the others contain Si. Na is not shown. This plot represents graphical solutions to (t_1O + t_1m) (Kroll and Ribbe, 1983).

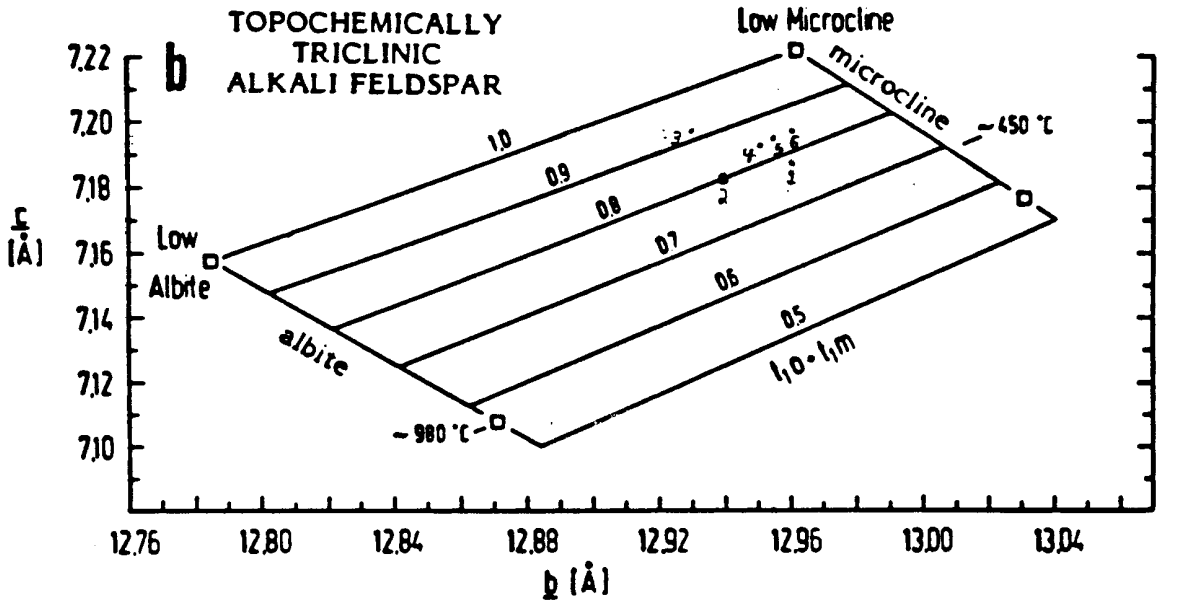

Figure 2. Plot of b versus c for topochemically triclinic alkali feldspar (Kroll and Ribbe, 1983).

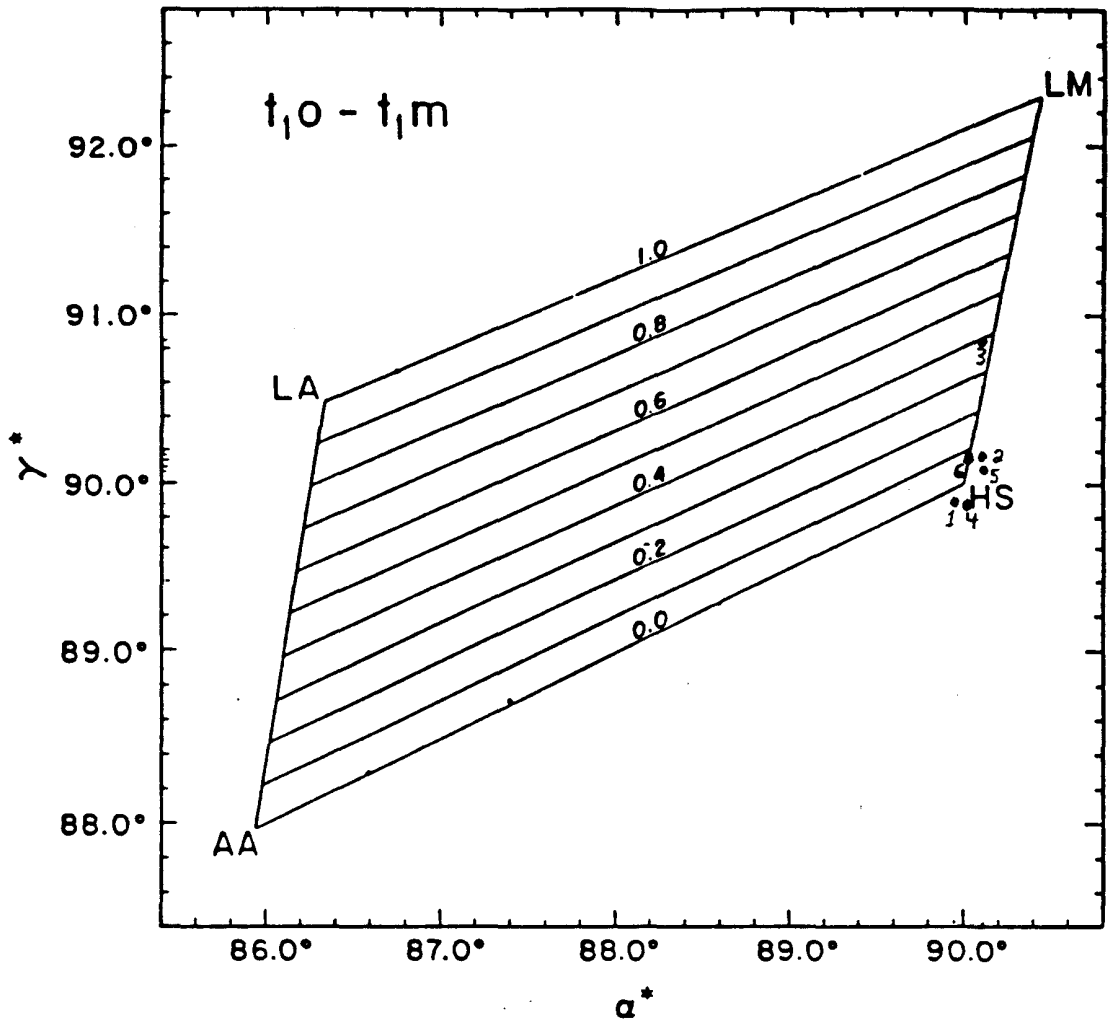

Figure 3. Plot of *- * alkali feldspars contoured for ($t_1o - t_1m$) with complete order in the low albite-low microcline series. t_1o equals t_1m in analbite and monoclinic feldspars. The estimated error in $t_1o - t_1m$ is 0.05 (Kroll and Ribbe, 1983).

CONCLUSION

The b-c plot for triclinic feldspars indicated that the composition of the Castle Crags specimens was that of an intermediate microcline, which has $t_1 0$ values of .375 to .940 and .025 to .370 for $t_1 m$ (Kroll and Ribbe, 1983). The only sample to fall significantly out of this range was CC-3. Values on the b-c plot do vary with values calculated using the $(t_1 0 + t_1 m)$ equation. The α^*-γ^* plot showed that the values for $(t_1 0 - t_1 m)$ plotted outside of the contours near the high sanidine corner. A propagation of error analysis for $(t_1 0 - t_1 m)$ showed that the observed values were not significant. Another reason for the values plotting outside the contours was that γ^* angles were consistently lower than 90.2°.

The potassium feldspar megacrysts, based mainly on data for $(t_1 0 + t_1 m)$, indicate that these feldspars are triclinic. Values for $(t_1 0 + t_1 m)$ range from .78 to .88. There was no relationship detected between phenocryst size and Al,Si order that could be determined from the data.

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